https://doi.org/10.20965/jrm.2020.p1211

Development Report:

Rapid Development of a Mobile Robot for the Nakanoshima Challenge Using a Robot for Intelligent Environments

Tomohiro Umetani, Yuya Kondo, and Takuma Tokuda

Department of Intelligence and Informatics, Konan University
8-9-1 Okamoto, Higashinada, Kobe, Hyoto 658-8501, Japan
E-mail: umetani@konan-u.ac.jp
[Received June 8, 2020; accepted November 17, 2020]

Automated mobile platforms are commonly used to provide services for people in an intelligent environment. Data on the physical position of personal electronic devices or mobile robots are important for information services and robotic applications. Therefore, automated mobile robots are required to reconstruct location data in surveillance tasks. This paper describes the development of an autonomous mobile robot to achieve tasks in intelligent environments. In particular, the robot constructed route maps in outdoor environments using laser imaging detection and ranging (LiDAR), and RGB-D sensors via simultaneous localization and mapping. The mobile robot system was developed based on a robot operating system (ROS), reusing existing software. The robot participated in the Nakanoshima Challenge, which is an experimental demonstration test of mobile robots in Osaka, Japan. The results of the experiments and outdoor field tests demonstrate the feasibility of the proposed robot system.

Keywords: mobile robot, intelligent environment, Nakanoshima Challenge, robot operating system (ROS)

1. Introduction

With the recent developments in autonomous mobility technologies for mobile robots, various service robots have been proposed to provide services in urban environments such as autonomous transportation robots that deliver products to their destinations and security robots that patrol streets. Aiming for a society in which humans and robots coexist, robot challenge events are organized. Examples are the Tsukuba Challenge [1] and Nakanoshima Challenge [2, 3, a]. These events provide various challenges for mobile robots, such as identifying moving objects, detecting a target person, and recognizing the environment to comply with traffic laws and regulations. To address these challenges, researchers have developed various autonomous robots [4–8] and techniques for autonomous robot services such as mapping, navigation, recognition, and control algorithms.

This paper reports on the development of an autonomous mobile robot designed to complete tasks in intelligent environments. The robot participated in the Nakanoshima Challenge, which is an experimental demonstration test of mobile robots [9]. Recently, the construction of an intelligent environment based on multipoint ambient sensing was studied in robotics and system integration [10]. In these studies, data on the physical position of personal electronic devices or mobile robots were important for information services and robotic applications. In an intelligent environment, humans and robots may use sensor devices to obtain location-related information to complete their tasks. Thus, correlating the sensor information with location information from the records of the measurements is necessary. We have conducted several studies, such as the probabilistic localization of mobile clients in multi-storied buildings [11], localization of mobile robots in environments with translucent objects such as windows and shrubberies [12], and sensor data fusion for localization in indoor structures [13]. Overall, automated mobile robots must acquire precise location data in an intelligent environment.

We verified the performance of the autonomous mobile robot in various tasks, such as mapping, navigation, control algorithm, and data acquisition to construct intelligent environments. In addition, we aimed to develop a safe and reliable service robot that can autonomously move in an urban environment. Hence, we aim to construct a safe autonomous robot for intelligent environments according to the safety regulations and rules of the Nakanoshima Challenge.

In this study, we used the software packages of a robot operating system (ROS) [14, b] reusing the software developed for existing robots. In addition, to save time, we used a mobile robot base for which ROS software packages already have been developed. Importantly, we analyzed the results of outdoor field tests particularly safety measures from robotic challenge regulations to evaluate the feasibility of the developed robotic system.

2. System Design for a Mobile Robot Platform for the Nakanoshima Challenge

This section describes the system design of the robot developed for the Nakanoshima Challenge. First, we present the mobile robot technology that is required to construct an intelligent environment and provide services. Second, we describe the goals and task settings of the robotic challenge. Third, we detail the hardware configurations of the developed mobile robot. Finally, we outline the design of the control system.

2.1. Mobile Robot to Construct an Intelligent Environment

This subsection describes a mobile robot that constructs an intelligent environment system to provide services in this system. In previous studies, various sensors and network infrastructures were installed to construct an intelligent environment [10]. In these environments, the robot completes the required tasks based on the data collected from the environmental sensors.

In an intelligent environment, humans and robots may use sensor devices to obtain location-related information to complete their tasks. Therefore, the placement of sensors when constructing an intelligent environment should be planned to ensure optimal coverage and avoid blind spots. Location information must be acquired using the information transmitted by the communication and spatial infrastructure of the devices used by humans or robots. In addition, the sensor information must be correlated with the location information using measurement records. Therefore, a mobile robot must run in the environment automatically to construct an intelligent environment.

Moreover, the technique of correlating location and sensor information is linked to map generation and autonomous navigation techniques in the mobile robot challenge. In this challenge, changes in the environment, such as the attachment of the sensors and use of information acquired by the other sensory data are not permitted; however, we constructed a map based on the measurement records acquired by the mobile robots before the navigation experiment was conducted. In addition, mobile robots are used to provide services in intelligent environments, and network systems and middleware are required to construct these environments. System integration of middleware is a challenge in the construction of environmental services.

The aim of this study was to develop a mobile robot that can collect location information to build an intelligent environment and provide services. In addition, through the public experiments of the robot challenge, we demonstrated the minimum development policy for outdoor public robot experiments and problems to be considered when applying an indoor robot to the outdoor environment. We developed human-safe robots that can participate in robotic challenges. Moreover, we verified the feasibility of the sensing and other functions of the robot to construct an intelligent environment.

2.2. Goals and Task Settings for the Robot Challenge

This subsection explains our goals and task settings for the robot challenge. Robots participating in the Nakanoshima Challenge have safety limitations, such as the maximum and minimum size of the robots, visibility, portability, and versatility. In addition, to construct an intelligent environment for service robots, data on the physical location of personal electronic devices or mobile robots are important. Therefore, we set the following development objectives to participate in the robotic challenge:

1. The robot must comply with safety measures to move autonomously in an environment in which people are present.

2. The robot must acquire data on its physical location to construct an intelligent environment.

3. The robot can be operated by a non-expert.

These requirements are detailed as follows. First, the robot must be safe to move autonomously in an intelligent environment with people. Safety equipment is often installed insufficiently to the base of research robots initially. However, regulations, such as laws and the rules of buildings, must be complied with when operating the robot autonomously in the public space. Therefore, sufficient safety measures should be undertaken for a robot that collects information in an environment with people. In this study, we implemented an emergency button switch to comply with the regulations of the public experiment with minimum development. Subsequently, the layout of the switch was improved through the experience of a public experiment in the Nakanoshima Challenge to enhance the safety of the mobile robot.

Second, the robot must acquire location-related information for map collection in an intelligent environment. To accomplish this, the robot must navigate using the map provided in advance, and a map must be generated for the robot to act based on the motion results. A sensor system to avoid accidents such as contact with a person or an object is not a sufficient specification for developing robots. To generate a map to correlate location information in an intelligent environment, a sensing system that can accurately acquire shapes is required. Therefore, the robot was equipped with internal sensors and a horizontal laser range sensor system.

Third, the robot should be operated by both the developers and non-specialists. This robot must be used to collect information and provide services in an intelligent environment. Therefore, developers and users may be different people although the robot was developed for laboratory experiments. We have conducted studies on robot control systems for demonstrators [15] and the integration of the control interfaces of multiple robot systems to simplify the hardware operations and reduce the burden on the operators during a demonstration [16]. In a robot laboratory in which development members change, adopting

Fig. 1. Appearance of the developed robot URI-Konan for the Nakanoshima Challenge 2019.

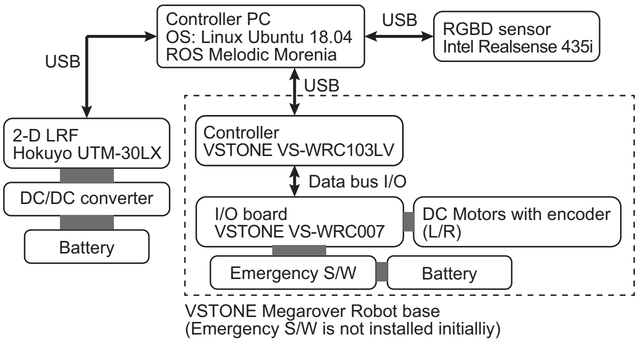

Fig. 2. Hardware configuration of the developed robot system.

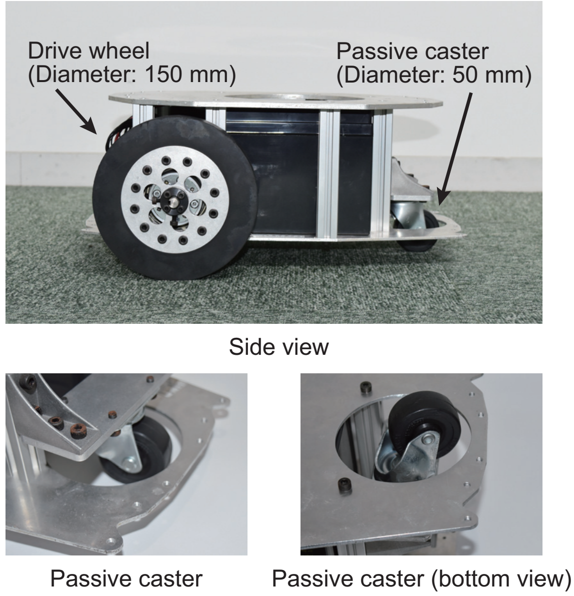

Fig. 3. Appearance of the robot base for the mobile robot system.

a robot development platform that is open and has open examples is expected to enable continuous, reproducible development. Additionally, by adopting an open software development platform, we can expect to engage in discussions with other research communities. In this implementation, we adopted the ROS, which is an open-source robot middleware, to reuse software assets because several development examples for mobile robots exist.

2.3. Hardware Configuration for the Developed Mobile Robot

This subsection describes the hardware configuration of the developed mobile robot. We selected hardware devices and constructed a robot system. **Fig. 1** shows the first appearance of the developed robot in the public experiment of the Nakanoshima Challenge 2019. The size of the mobile robot was 430 (W) mm $\times$ 600 (D) mm $\times$ 700 (H) mm. The robot's weight was approximately 20 kg, including the batteries of its base.

Figure 2 shows the system configuration of the developed robot. We adopted the VSTONE Megarover Ver.1.2, a differential-drive two-wheel mobile vehicle for the mobile robot base (**Fig. 3**). The payload of the robot carriage was 30 kg, and the front and rear wheels had diameters of 150 mm and 50 mm, respectively. The front and rear wheels had widths of 30 mm and 20 mm, respectively. Each wheel was fabricated from hard rubber and was not easily deformed by the terrain. The rear passive caster was attached to the frame of the robot directly and could change direction following the direction of movement of the robot. For the external sensors, a Hokuyo UTM-30LX (Top-URG) sensor was used for the two-dimensional laser imaging detection and ranging (2D-LiDAR) system and an Intel RealSense D435i camera was used as the RGB-D sensor. The sensors were attached at heights of 350 mm and 650 mm above the ground, respectively. 2D-LiDAR was primarily used for map generation and self-location recognition, and the RGB-D sensor was used for sensing in service task missions.

A push-button emergency stop switch with normally closed contacts was installed at the top of the robot. If the robot acted abnormally or there was a risk of collision, the switch could be pressed to switch off the current in the motor driver of the robot carriage to completely stop the robot. In the first public experiment, the emergency stop switch was placed on the top plate of the mobile robot, near the control PC, to comply with the experiment regulations. The switch was conspicuously fixed to the robot to improve the safety of the experiment, according to the advice of the committee members of the robot challenge. **Fig. 4** shows the appearance of the robot developed for the extra-challenge public experiment. Safety was improved for this additional experiment because of the refined layout of the emergency stop switch and the wiring of the power supply and data communication cables.

The mobile robot was controlled using a generic notebook PC with the Ubuntu 18.04 operating system. The robot's microcontroller, VSTONE VS-WRC103LV, and sensors were directly connected via a universal serial bus (USB). The host PC communicated with the robot controller VS-WRC103LV via serial communication [c].

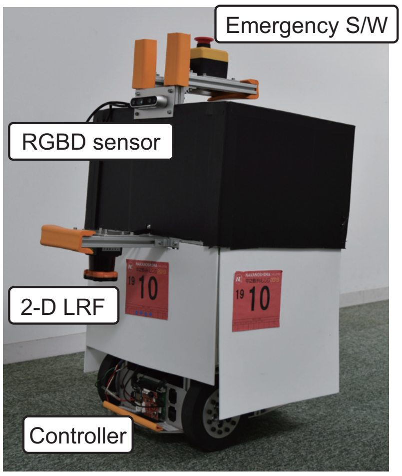

Fig. 4. Appearance of the refined robot, URI-Konan (a), for the extra challenge of Nakanoshima Challenge 2019.

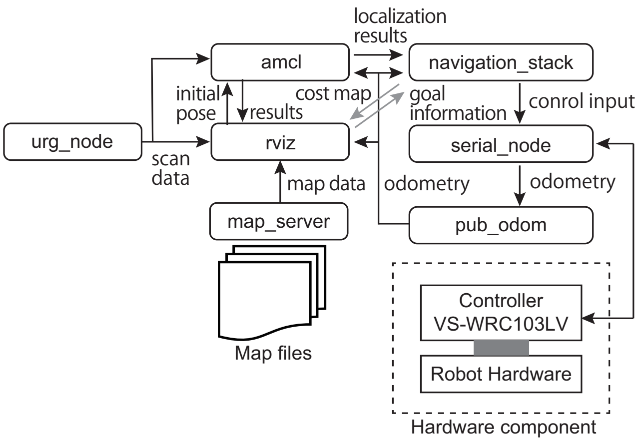

Fig. 5. Software configuration for the navigation system.

2.4. Control-System Design for the Developed Mobile Robot

This subsection explains the design of the control system for the mobile robot. The robot control system was constructed based on ROS Melodic Morenia, which is an open-source robot middleware. Many software packages for mobile robots have been reused.

We constructed a navigation system based on navigation stack packages for the ROS. **Fig. 5** shows the software configuration of this navigation system. The arrows that connect software packages indicate the information sent by these packages. The system used the *move_base* navigation stack modules [d] and the *amcl* Monte Carlo localization modules. We adopted *rviz* as a 3D visualizer for the navigation experiment. The *urg_node* node output the scan data obtained by the laser range finder [e]. The map files were constructed in advance through a mapping experiment using the mobile robot and the simultaneous localization and mapping (SLAM) algorithm.

The cartographer algorithm package [17] was adopted for SLAM because of the following properties:

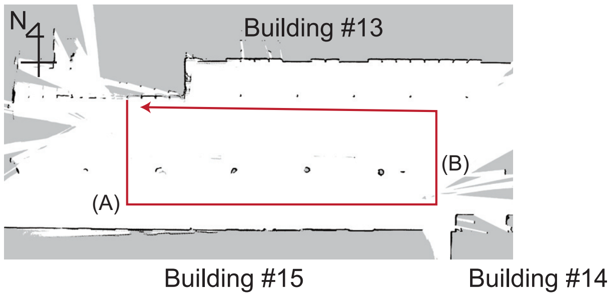

Fig. 6. Illustration of the route for map construction.

1. The algorithm can explicitly detect the loop closure of the trajectory of a mobile robot, which can improve the mapping.
2. When executing the software part of the robot system, real-time online SLAM can be executed while the robot is running; therefore, the mapping results can be easily checked during the map construction experiment.
3. The algorithm can be applied for 3D SLAM using the same software package, which will reduce the number of changes for the robot software platform in future system expansions.

In addition, a review of autonomous navigation robots indicated that graph-based SLAM is becoming mainstream [14]; thus, we used this information as a reference when selecting an algorithm.

In this study, we included an RGB-D sensor to capture the front view of the robot. The RGB-D sensor was used to evaluate experiments, visualize results, and develop a person detection system based on a single-shot multibox detector [18]. The RGB-D sensor software was executed separately from the control software packages of the robot. Future studies may include the detection and recognition of target persons and objects, which can be used to control the robots.

The development time was reduced by reusing the software packages of ROS. In addition, the control parameters, range of measurement, and arrangement of the sensors were adjusted for the experiment. In the following sections, we present the results of the experiments and robotic challenge.

3. Experiment

This section describes the map generation and navigation experiment in an outdoor environment to verify the developed system. The experiment was conducted in an outdoor courtyard surrounded by university buildings. **Fig. 6** depicts the map construction route in the experimental environment. The arrow indicates the route of the robot for map construction. Near the start position (the entrance to the building), glass walls were used. The experiment was conducted by setting the route on the paths

(a) View from point (A)   (b) View from point (B)

Fig. 7. Experimental environment. (A) and (B) are corresponded to the points shown in **Fig. 6**.

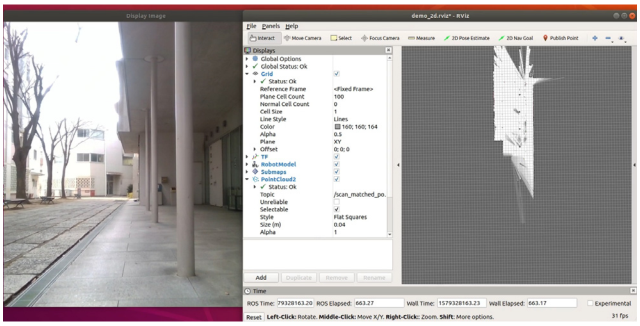

Fig. 8. Example of a camera image and mapping results in the map construction experiment.

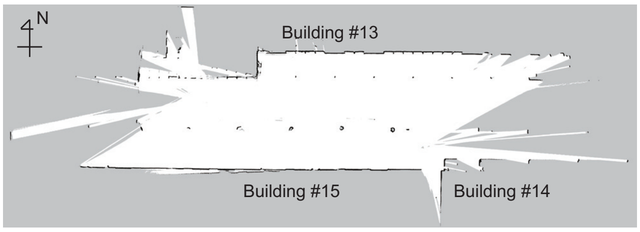

Fig. 9. Mapping result.

paved with flat cobblestones or bricks. **Fig. 7** shows the views of the experimental environment. **Fig. 8** shows an example of a camera image obtained by the RGB-D sensor and the results of the map construction experiment.

The experiment was conducted as follows. The robot was controlled using a gamepad connected by a wire. First, a map of the experimental environment was created using the cartographer algorithm package. Next, the robot could move autonomously based on the generated navigation map. The generated map and results of the autonomous outdoor movement were evaluated in the experiment. The parameters of the cartographer algorithm and navigation packages were determined experimentally.

At the time of map generation, as shown in **Fig. 6**, the mobile robot moved straight from the entrance of Building #13 and through the brick-lined passage on the side of Building #15. Next, the robot moved through the brick-lined passage between Buildings #14 and #15 toward Building #13 and on the flat cobblestone passage on the side of Building #13, not moving on the uneven path shown in the center of **Fig. 7**, as shown in **Fig. 8**. Subsequently, the robot moved to the entrance to Building #13. Finally, the system closed the loop of the robot's path for map generation to adjust the sensing data. In addition, we set a path that would follow the same route as when the map was generated, and we let the robot move autonomously along the planned path.

Figure 9 shows the generated map based on the cartographer algorithm using the measurement results of the robot odometry and 2D-LiDAR. The figure confirms that the generated map could capture the experimental environment almost accurately with respect to the size of buildings and the span of pillars or trees in the map. In addition, the loop closure was detected successfully from the map. The corners of the buildings, spacing between buildings, and parallelism are shown on the map, which confirms the geometric consistency of the constructed map. The results of object detection also confirmed that high obstacles such as trees and poles were detected and included in the generated map, but low obstacles such as benches were not detected and were not registered in the generated map. This was caused by the mounting height of the laser rangefinder, and we observed that the laser beam passed vertically over the bench. In addition, the west side of the generated map shown in **Fig. 9** confirmed that the laser beam was transmitted through the glass wall and reflected by the nontransparent wall.

Next, we evaluated the autonomous movement of the robot using navigation software packages. Two paths were set for the navigation experiment. One was the same as the map-making route (counter-clockwise path), and the other was a route proceeding clockwise from the flat stone pavement in front of Building #13. In the counter-clockwise path, the robot slipped on the drive wheels in a brick-lined passage; after traveling several meters, it had difficulty driving autonomously. In the clockwise path, although the robot moved autonomously in the flat ground passage on the side of Building #13, its rear caster became stuck when it reached the brick passage beyond the groove lid connecting Buildings #13 and #15. The stack created difficulty for the robot to move.

According to the mapping results, the robot could correctly register the location information in the environment. In addition, we confirmed the feasibility of basic self-position estimation, map generation, and route planning by the developed robot. We confirmed that the results demonstrated the feasibility of the registration of the location information in the environment to the map, which is a necessary function to correlate sensor information with location information using the measurement records for the intelligent environment. However, the results were strongly affected by the inclination of the road surface in the navigation experiment. In future studies, we plan to register glass walls on the map by collation with other sensor information, develop a probabilistic model, and detect the glass walls in the navigation tasks. In addition, the research will include improvements in the moving mechanism (in terms of performance) and the motion planning section of the robot control system.

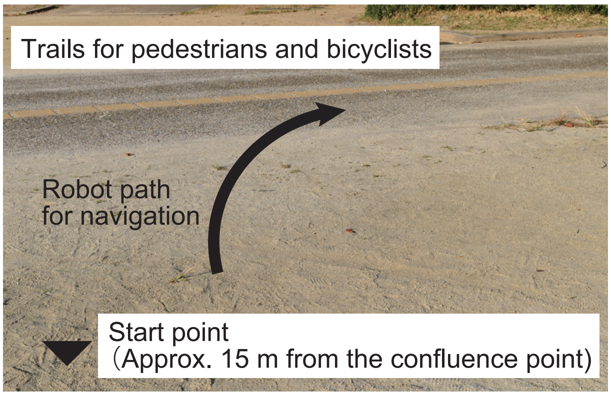

Fig. 10. Confluence point of the trails in the parks and the start area for the extra challenge in the Nakanoshima Challenge.

4. Results for the Nakanoshima Challenge 2019

In this section, we present the results of our system in the Nakanoshima Challenge 2019, held in September and December 2019. In the experimental test in September, self-sustained location estimation did not function during autonomous driving by navigation; as a result, autonomous movement from the start point was not possible.

Figure 10 shows the confluence point of the pedestrian and bicycle trails in the park and the start area for the experiment of the Nakanoshima Challenge 2019 extra challenge held in December. After the beginning of the movement from the starting point, the robot was required to move for approximately 15 m on a dirt ground in the experiment. In the public experiment, the robot began to move autonomously, but the rear caster was stuck in the soil and sloping ground. Thus, the movement was interrupted within the start area in the experimental demonstration test.

The rear caster did not function for the following reasons. First, the mobile robot cart used was designed for indoor movement and was weak on the road surface slope. In addition, because of the driving wheels and rear passive caster of the robot without elasticity, the robot had difficulty following the changes in the road surface changes. Therefore, owing to insufficient friction between the wheels and the road surface, the robot was unable to regain grip when the driving wheels were idled in relation to the robot and the ground. This resulted in continuous idling and, consequently, it became stuck in the dirt ground.

Second, because the non-driven passive caster was directly attached to the robot body, the contact with the ground could not be controlled by the spring and damper of the mechanism. Solving the problem of idling became difficult in autonomous driving because the control parameters were not optimal. In addition, the small radius of the passive caster and the inability of the mechanism to absorb vibrations from the road surface reduced the driving performance in the robot challenge experiment.

As many outdoor mobile robots have been adopted, we confirm that passive casters are not the casters used in indoor robots; mechanisms that can absorb vibrations from the road, such as spring casters, are required. In addition, the distance between the bottom of the robot body and the roadway and the size of the wheels are also important in overcoming the problem of the step height between the sidewalk and roadway surface. Therefore, the arrangement of driving and non-driving wheels must be improved to enable the robot to move on an inclined surface (such as a slope), which will be realized in a future study.

However, we could perform map generation experiments and navigation experiments on a flat road surface environment. In the map generation experiment, we confirmed the feasibility of collecting location-related information. In addition, by examining the difficulty of moving the robot on uneven terrain, we demonstrated the minimum development policy for outdoor public robot experiments and problems to be considered when applying the indoor robot to the outdoor environment.

According to the results of the outdoor challenge, the mobile robot does not have sufficient robustness or experimental experience. However, this study enabled us to identify problems such as mechanism improvement for the next robot challenge. Future challenges include the adoption of a high-performance moving mechanism, improvement of map generation and route planning, and development of ROS packages that can interactively generate and specify routes. In addition, future research will include the accumulation of experience in many outdoor experiments, indoor map generation, and navigation.

5. Conclusion

This paper describes the development of an autonomous mobile robot to complete tasks in intelligent environments. In this research, we constructed a robot system for an outdoor environment and verified its autonomous movement using an ROS. If the road surface was not flat, the rear wheel casters of the robot were stuck, and the autonomous movement was interrupted. However, the experiments enabled us to evaluate the self-location estimation, map generation, and autonomous movement using route planning. The feasibility of the system was evaluated in an outdoor experiment and an experimental operation in a robot challenge.

In future research, we plan to adopt a high-performance moving mechanism, improve map generation and route planning, and develop ROS packages that can interactively generate and specify routes. The arrangement of the driving and non-driving wheels must be improved to enable the robot to move on an inclined surface (such as a slope in the indoor/outdoor environment). We also plan to improve the collection of position-related information to construct an intelligent environment and develop service applications in this environment using the proposed robot system.

Acknowledgements

This work was supported in part by JSPS KAKENHI Grant Numbers JP17K06280, JP17H01801, and JP18K11416, and MEXT, Japan. The authors thank the committee members of Nakanoshima Challenge 2019 for productive discussions on the outdoor field experiments.

References:

[1] S. Yuta, "Tsukuba Challenge: Open Experiments for Autonomous Navigation of Mobile Robots in the City – Activities and Results of the First and Second Stages –," J. Robot. Mechatron., Vol.30, No.4, pp. 504-512, 2018.

[2] T. Takubo, S. Aoyagi, Y. Inoue, A. Imazu, and K. Ikoma, "Report of Nakanoshima Challenge 2019," Proc. 20th SICE System Integration Division Conf., pp. 1937-1938, 2019 (in Japanese).

[3] T. Takubo, "Recommendation of Participating Robotics Challenges," Proc. 63rd Annual Conf. of the Institute of Systems, Control and Information Engineers, pp. 685-688, 2019 (in Japanese).

[4] T. Tomizawa, M. Shibuya, R. Tanaka, and T. Nishida, "Developing a Remotely Operated Portable Mobile Robot," J. Robot. Mechatron., Vol.30, No.4, pp. 584-590, 2018.

[5] Y. Aotani, T. Ienaga, N. Machinaka, Y. Sadakuni, R. Yamazaki, Y. Hosoda, R. Sawahashi, and Y. Kuroda, "Development of Autonomous Navigation System Using 3D Map with Geometric and Semantic Information," J. Robot. Mechatron., Vol.29, No.4, pp. 639-648, 2017.

[6] A. Shimizu, T. Koide, Y. Fujiwara, and A. Imadu, "Development of Mobile Robot in Machine Dynamics Laboratory of Osaka City University for Tsukuba Challenge 2017," Proc. 18th SICE System Integration Division Conf., pp. 1210-1212, 2017 (in Japanese).

[7] T. Takubo, Y. Uchibori, and A. Ueno, "Introduction for Development of the Mobile Robot of Osaka City University in 2016," Proc. 17th SICE System Integration Division Conf., pp. 96-98, 2016 (in Japanese).

[8] T. Eda, T. Hasegawa, S. Nakamura, and S. Yuta, "Development of Autonomous Mobile Robot "MML-05" Based on i-Cart Mini for Tsukuba Challenge 2015," J. Robot. Mechatron., Vol.28, No.4, pp. 461-469, 2016.

[9] T. Umetani, Y. Kondo, and T. Tokuda, "Development of Mobile Service Robot from Robotics Laboratory at Konan University for Nakanoshima Challenge 2019," Proc. 20th SICE System Integration Division Conf., p. 1934, 2019 (in Japanese).

[10] J. H. Lee and H. Hashimoto, "Intelligent Space – concept and contents," Adv. Robotics, Vol.16, No.3, pp. 265-280, 2002.

[11] T. Umetani, T. Yamashita, and Y. Tamura, "Probabilistic Localization of Mobile Wireless LAN Client in Multistory Building Based on Sparse Bayesian Learning," J. Robot. Mechatron., Vol.23, No.4, pp. 475-483, 2011.

[12] M. Tanaka, M. Wada, T. Umetani, and M. Ito, "Detection of Mobile Objects by Mixture PDF Model for Mobile Robots," Trans. of the Institute of Systems, Control and Information Engineers, Vol.25, No.11, pp. 323-327, 2012.

[13] T. Umetani, S. Yamane, and Y. Tamura, "Indoor Localization for Augmented Reality Aided Operation and Maintenance System based on Sensor Data Integration," Plasma and Fusion Research, Vol.9, No.3406054, pp. 1-4, 2014.

[14] Y. Hara, "Autonomous Navigation with ROS," J. Robotics Society of Japan, Vol.35, No.4, pp. 286-290, 2017 (in Japanese).

[15] T. Umetani, D. Kiyose, H. Sakakibara, S. Aoki, and T. Kitamura, "Component-based Tabletop Robot System Executed on a Self-Contained Micro Controller," Trans. of the Society of Instrument and Control Engineers, Vol.54, No.1, pp. 126-128, 2018 (in Japanese).

[16] T. Umetani, S. Aoki, T. Kitamura, and A. Nadamoto, "System Integration for Component-Based Manzai Robots with Improved Scalability," J. Robot. Mechatron., Vol.32, No.2, pp. 459-468, 2020.

[17] W. Hess, D. Kohler, H. Rapp, and D. Andor, "Real-Time Loop Closure in 2D LIDAR SLAM," Proc. the 2016 IEEE Int. Conf. on Robotics and Automation, pp. 1271-1218, 2016.

[18] W. Liu, D. Anguelov, D. Erhan, C. Szegedy, S. Reed, C.-Y. Fu, and A. C. Berg, "SSD: Single Shot MultiBox Detector," Proc. European Conf. on Computer Vision (ECCV 2016), Lecture Notes in Computer Science, Vol.9905, pp. 21-37, 2016.

Supporting Online Materials:

[a] Nakanoshima Challenge 2019.
http://www.proassist.co.jp/nknsmchallenge.html
[Accessed May 28, 2020]

[b] ROS. http://wiki.ros.org/ [Accessed May 28, 2020]

[c] Rosserial metapackage. http://wiki.ros.org/rosserial [Accessed May 28, 2020]

[d] Navigation stack. http://wiki.ros.org/navigation [Accessed May 28, 2020]

[e] Urg_node. http://wiki.ros.org/urg_node [Accessed May 28, 2020]

Name:
Tomohiro Umetani

Affiliation:
Associate Professor, Department of Intelligence and Informatics, Konan University

Address:
8-9-1 Okamoto, Higashinada, Kobe, Hyogo 658-8501, Japan

Brief Biographical History:

2004- Postdoctoral Fellow, Osaka University
2005- Research Associate, School of Design and Architecture, Nagoya City University
2008-/2012- Lecturer / Associate Professor, Konan University

Main Works:

• "System Integration for Component-Based Manzai Robots with Improved Scalability," J. Robot. Mechatron., Vol.32, No.2, pp. 459-468, 2020.
• "Scalable Component-Based Manzai Robots as Automated Funny Content Generators," J. Robot. Mechatron., Vol.28, No.6, pp. 862-869, 2016.
• "Probabilistic Localization of Mobile Wireless LAN Client in Multistory Building based on Sparse Bayesian Learning," J. Robot. Mechatron., Vol.23, No.4, pp. 475-483, 2011.

Membership in Academic Societies:

• The Japan Society of Mechanical Engineers (JSME)
• The Robotics Society of Japan (RSJ)
• The Institute of Electrical and Electronics Engineers (IEEE)

Name:
Yuya Kondo

Affiliation:
Student, Department of Intelligence and Informatics, Konan University

Address:
8-9-1 Okamoto, Higashinada, Kobe, Hyogo 658-8501, Japan

Brief Biographical History:

2016-2020 Student, Department of Intelligence and Informatics, Konan University

Main Works:

• "Development of Mobile Service Robot from Robotics Laboratory at Konan University for Nakanoshima Challenge 2019," The 20th SICE System Integration Division Annual Conf. (SI 2019), p. 1934, 2019 (in Japanese).
• "ROS-based Outdoor Mobile Platform for Robotics Challenge," Proc. of the 64th Annual Conf. of the Institute of Systems, Control and Information Engineers (ISCIE), pp. 166-168, 2020 (in Japanese).

Name:
Takuma Tokuda

Affiliation:
Student, Department of Intelligence and Informatics, Konan University

Address:
8-9-1 Okamoto, Higashinada, Kobe, Hyogo 658-8501, Japan

Brief Biographical History:
2016-2020 Student, Department of Intelligence and Informatics, Konan University

Main Works:
- "Development of Mobile Service Robot from Robotics Laboratory at Konan University for Nakanoshima Challenge 2019," The 20th SICE System Integration Division Annual Conf. (SI 2019), p. 1934, 2019 (in Japanese).
- "ROS-based Outdoor Mobile Platform for Robotics Challenge," Proc. of the 64th Annual Conf. of the Institute of Systems, Control and Information Engineers (ISCIE), pp. 166-168, 2020 (in Japanese).